Journal of Forestry Research (2011) 22(1): 77–82
DOI 10.1007/s11676-011-0129-0

ORIGINAL PAPER

Evaluation of management tools for the control of poplar leaf defoliators (Lepidoptera: notodontidae) in northwestern India

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Received: 2009-08-04 Accepted: 2010-02-16

Abstract: *Populus* suffers from multiple insect damage throughout its distributional range in northwestern India. The evaluation of various management tools was done based on the hypothesis that manipulation of insect habitat can provide tangible results. Manipulation of cultural practices, ploughing of field during December, and growing of crops (wheat, *Trifolium alexandrinum* and others) results in lower adult emergence, reduced leaf infestation, number of larvae and pupae per meter branch length of poplar leaf defoliators (PLD). Fallow plantations were more prone to attack of PLD than intercropped plantations. Higher incidence of *Clostera restitura* was recorded in southwestern dry zones due to unsuitability of the site, poor quality of irrigation water and dry weather conditions. Complete stripping of *Populus* trees does not occur in low temperature & high humidity, submountaneous zones of Punjab. Chemical control studies were conducted in laboratory & field conditions, and among the five insecticides tested, Profenophos 50 EC, Quinalphos 25 EC and Carbaryl 50 WP @ 0.05 and 0.1 percent concentration gave consistently high mortality of PLD larvae up to 21 days after spraying. Use of insecticides prior to peak activity periods & during evening hours enhances the efficiency of management options.

Keywords: abundance; control; *Clostera* sp.; distribution; *Populus*

Introduction

Populus deltoides Batr. Ex. is being widely cultivated across the northwestern Indian plains (Punjab, Haryana, Uttaranchal and Uttar Pradesh provinces of India). The species is best suited for farm lands in northern plains (well drained sandy loam soils). Poplars show excellent potential in agroforestry systems due to their high biomass yield and regeneration ability (Coyle et al. 2000). Further, its fast growth (short rotation 5–6 years in riverside belts & 5–8 years elsewhere), high productivity (>30 $m^3 \cdot ha^{-1} \cdot a^{-1}$), winter deciduous nature (Singh et al. 2004) and compatibility as an intercrop with a wide range of arable, vegetable and fodder crops make the species favourite among the farmers. It is primarily cultivated as boundary plantings, block/rows of trees in cropped areas (7 m × 3 m spacing) and also intercropped with annual crops (Kharif season : fodder-Bajra, Rabi season (Nov-March) : wheat/barseem etc.) throughout this region.

Most of the exotic poplars (especially *P. deltoides*) have suffered multiple insect injuries since their introduction in India. A total 132 species belonging to 42 families and nine orders have been recorded from various species of *Populus* in India (Ahmad et al. 2001). Large scale epidemic defoliation of *P. deltoides* (clone G-3, G-48 of 3–4 years old) by *Clostera fulgurita* (Walker) and *Clostera restitura* (Walker) have been reported throughout the distributional range in northwestern India. Poplar leaf defoliators (PLD) are considered as the major defoliators of *Populus* spp. as their wide distribution (Four states of northwestern India), causing significant growth loss to plantation over a large area and over consecutive years, and the damage more than 50% of the plantations leading to tree mortality in some cases (Singh et al. 2004).

Clostera (both *C fulgirita* & *C restitura*) have two different feeding modes. Early instars (1–3) feed gregariously and skeletonise the leaves by chewing the softer portion of the leaves and leaving the veins untouched. The leaf appears parched. Later instars (4–5) are solitary feeders that feed on the entire leaves (Sangha & Sohi 2007). This change in feeding behavior is likely to affect the degree of insecticide exposure experienced by the larvae within the same generation, particularly for chemicals that act solely by ingestion. Further, during the winter months the larval growth, development and food consumption are slow compared to summer months. The seasonal differences are therefore likely in larval responses to insecticidal exposure. Although broad spectrum and selective insecticides are available for the control of lepidopteran pests in northwestern India, however, no insecticides are currently recommended for the management of the PLD. The effectiveness of these insecticides needs to be quantified before any recommendation can be made. This study

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presents a series of dose response trials that were conducted during different seasons over the years to test the efficacy of chemicals against PLD.

The author further worked on the hypothesis that the manipulation of the insect/pest habitat in a manner that makes it less suitable for population growth of the defoliator can be a viable management option. Manipulation of habitat using cultural practices (tillage, intercropping of agricultural crops, irrigation etc.) is a potentially attractive approach to management of PLD because it is inexpensive, effective and has low environmental impact. These practices may not eradicate the pest, but are useful in diminishing the pest population such that the probability of reaching defoliating levels is greatly reduced.

The overall objective of this study was to contribute towards a holistic management strategy for PLD. The specific objectives were to (1) evaluate/document the effectiveness of the insecticides, (2) study the effect of cultural practices on PLD populations, and (3) modify the habitat such that the population growth of PLD is diminished/hampered.

Materials and methods

Study area

Random sampling surveys at monthly intervals were conducted from 2000 to 2005 in different districts of different agro climatic zones of Punjab (Fig. 1). Plantations (30) and nurseries (50) were selected in the three major agro climatic zones of Punjab viz., *kandi* zone, central plains and southwest zone. The data on the incidence of PLD, *C. restitura and C. fulgurita* were recorded by selecting at least five nurseries and three plantations in each district and 100 trees at each location.

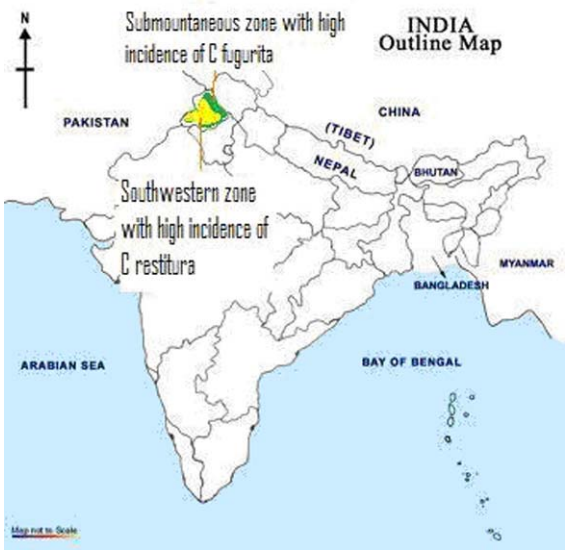

Fig 1. Map depicting areas of high incidence of *Clostera* spp in Northwestern India surveyed during 2000-2005.

The studies were also conducted on the seasonal fluctuation in the incidence of PLD on poplar during different months of the year from January 2000 to December 2003 at Forestry Area, Punjab Agricultural University, Ludhiana.

Cultural control trials

Effect of burying of pupae on the adult emergence of PLD

Seventy five healthy pupae each were buried in soil at a depth of 5 cm, 10 cm and 15 cm (i.e. 25 pupae per depth per replication). Twenty five pupae were kept on the ground surface as control. The area was covered with split cages. The cages were observed for emergence of adults daily. The pupae kept on the ground served as control. Mean moth emergence per treatment was worked out.

Effect of intercropping, tillage and irrigation on adult emergence of PLD

This experiment was conducted at Forestry Research Farm, Punjab Agricultural University, Ludhiana during 2002 and 2003. The experiment was conducted on 20 m × 16 m area in a randomized block design having 5 m × 4 m plot size. There were four plots each of poplar + wheat (*Triticum aestivum*), poplar + barseem (*Trifolium alexandrinum sativa* L.), poplar + fallow (ploughed) and poplar + fallow (unploughed). Fifty fully grown fifth instar larvae (ready to pupate) were kept at marked places in these plots before sowing of the crops. Recommended cultural practices (viz, presowing irrigation, ploughing/tillage, sowing of seeds, weeding etc.) were followed for raising these crops (wheat & barseem). In poplar + fallow (ploughed) treatment, the plot was ploughed two times at weekly interval during December, 2002. In poplar + fallow (unploughed) treatment, no cultural practices were followed and the larvae along with the leaf folds were retained at marked points as such. The marked areas were then covered by fastening muslin to four twigs. The muslin was buried under the soil to avoid the adults of PLD from escaping. The marked areas were observed twice a week for emergence of adults and the observations were carried on until there was no emergence for two consecutive weeks. The data was subjected to analysis of variance using randomized block design and critical differences were worked out.

Effect of cultural practices of crops on the incidence of PLD

Two plantations viz. fallow and intercropped i.e. in *Rabi* season – Poplar + Wheat (*T. aestivum*), and in *Kharif* season – Poplar + Bajra (*Pennisetum typhoides*) were selected at village Kumkalan, district Ludhiana, Punjab. The plantations were approximately 1 km apart. In the fallow plantation, the field was ploughed twice at 15 day interval during December, 2002. The leaves of poplar which fell on the ground during winters were collected and burned. In the intercropped plantation, normal cultural practices were followed for raising wheat and bajra. The incidence of PLD in these plantations during 2003 (March to November) was recorded at fortnightly intervals. Observations on the total number of leaves per twig (each 1 m length), the number of damaged leaves per twig, the numbers of larvae and pupae per meter

branch were recorded. Observations were recorded from four twigs per tree and five trees were observed randomly in both fallow and intercropped plantations. The data was subjected to analysis of variance using randomized block design.

Chemical control trials

Laboratory tests for evaluation of efficacy of different insecticides against PLD

The bioassay studies were conducted by using pretreated food and larvae method. The insecticides namely Quinalphos 25 EC (1 ml/L, 2 ml/L, 4 ml/L), Endosulfan 35 EC (0.75 ml/L, 1.5 ml/L, 3 ml/L), Profenophos 50 EC (0.5 ml/L, 1 ml/L, 2 ml/L), Cypermethrin 10 EC (2.5 ml/L, 5 ml/L, 10 ml/L), Carbaryl 50 WP (0.5 g/L, 1 g/L, 2 g/L) and control (water) were taken as treatments. All the insecticides were sprayed @ 0.025%, 0.05% and 0.1% concentrations in the final spray material. The leaves of potted poplar plants (grown in mudpots) were sprayed using a fine mist of different insecticides at different concentrations. In control, the leaves were sprayed with water. The treated leaves were plucked after 10 min of spraying and were placed in petri-plates. The larvae (freshly emerged third instar) that were obtained from the general culture maintained in the Entomology Laboratory, Department of Forestry & NR, PAU, Ludhiana, were treated uniformly using atomizer with different concentrations of the insecticides. The treated larvae were then released in petriplates on the pretreated food. A single larva was placed in each petriplate. In all there were 16 treatment combinations. The experiment was replicated six times. The percent larval mortality after 24 h and 48 h was calculated and the data was subjected to analysis of variance using completely randomized design (CRD).

Evaluation of field efficacy of different insecticides against PLD

Field trials were conducted from 2003 to 2005 at different locations throughout Punjab for testing the field efficacy of various insecticides at different concentrations. Field trials were conducted on three to four years old poplar plantations located in different agro climatic zones of Punjab. The insecticides found promising in laboratory studies were evaluated @ 0.025%, 0.05% and 0.1% concentrations for the first two years i.e. 2003 and 2004. Later the lowest concentration of 0.025% was discontinued due to poor results in the field (< 50% mortality). All the chemicals were tested in randomized block design with four replications.

Each insecticide was sprayed on 20 trees per replication with the help of foot sprayer. Further, the sprayer was mounted on a tractor trolley that was driven slowly in between the rows of the trees (poplar spacing 5 m × 4 m). The height of spray was up to 6.1–7.6 m. One untreated row was kept between the insecticide treated rows to avoid erroneous results owing to drift of the insecticidal spray material. Observations were recorded by counting number of larvae per meter branch length from four randomly selected branches per tree from different directions of the tree trunk with the help of a wooden ladder. Data were recorded before spray and 7, 15 and 21 days after spray (DAS). The data were subjected to analysis of variance using randomized block design.

Since the pre-treatment population did not vary uniformly in the field, percent reduction over control (PROC) was calculated using the formula (Flemming and Retnakaran 1985):

$$PROC = 100 \times \left(1 - \frac{Ta \times Cb}{Tb \times Ca}\right) \quad (1)$$

where PROC = Percent reduction over control; Ta = Population in treatment after spray; Tb = Population in treatment before spray; Ca = Population in control after spray; and Cb = Population in control before spray

Results

Zonal surveys of Punjab State over the years indicated that there are marked differences in the distribution of *C. restitura and C. fulgurita* throughout the state. High incidence (upto 100%) of *C. restitura* was noticed in southwestern zone (Bathinda Ferozepur, Faridkot and Sangrur districts) whereas incidence of *C. fulgurita* was more in *kandi* zone (Gurdaspur, Hoshiarpur and Ropar districts, upto 90%). Two peaks of defoliator larvae were recorded during 2000–2001, 2001–2002, and 2002–2003 (Fig. 2). The population buildup (based on percent leaf damaged per meter branch length) started from May in each year and the insect inflicted damage up to December (before hibernation). Two peaks, i.e. July & October were observed over the years. The incidence varied from 41.5% to 47.5% during July and 56.25% to 61.25% during October in 2000–2001, 2001–2002, and 2002–2003 (Fig. 2). A diurnal variation in PLD was also recorded in the field. The larvae (3rd, 4th, 5th instar) were mainly confined to the upper parts of poplar trees during morning hours. As the day progressed (increased heat and light intensity) the larvae particularly 3rd, 4th & 5th instars (solitary feeders) started descending the tree canopy and during evening hours were seen in the lower parts of the trees.

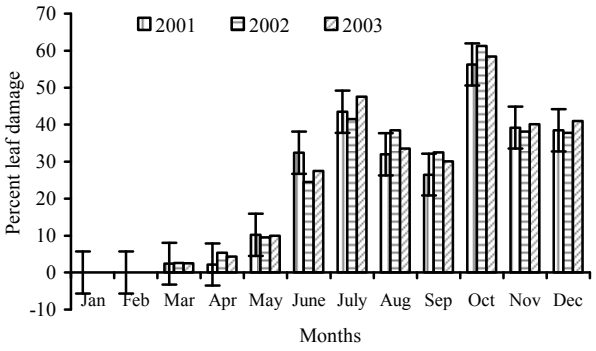

Fig. 2 Percent leaf damage by *Clostera restitura* and *Clostera fulgurita* during different months from 2000 to 2003.

Adult emergence of PLD was significantly affected by intercropping, tillage and irrigation [Critical difference (CD) = 7.45 at 5% level of significance] (Fig. 3). Minimum adult emergence

(49.5%) was recorded in poplar + wheat plot and maximum (83.0%) in poplar+ fallow (unploughed). Poplar + wheat (49.5%) and poplar + barseem (54.0%) were statistically at par with each other but showed significantly less adult emergence compared to poplar + fallow (ploughed) (67.5%) and poplar + fallow (unploughed)(83.0%). Further, adult emergence in poplar +fallow (ploughed) (67.5%) was significantly less than poplar + fallow (unploughed) (83.0%).

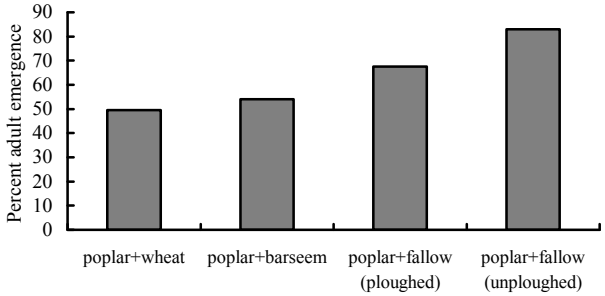

Fig. 3 Effect of tillage, irrigation and intercropping of poplar on the adult emergence of PLD

To confirm the above trend, pupae of PLD were buried in soil at three depths (5 cm, 10 cm and 15 cm). No adult emergence occurred when the pupae were buried, irrespective of the depth at which they were buried, whereas pupae placed on the surface showed 100% adult emergence.

Comparison of intercropped and fallow poplar plantations with regard to percent damaged leaves, larvae and pupae per meter branch length revealed that intercropping significantly reduced the PLD incidence during the year. Mean percent leaves damaged in fallow plantations (29.37) was higher than intercropped plantations (21.49) (Fig. 4 a). Percent leaves damaged during different months also varied significantly with maximum damage during October, 2003 (54.87%) and minimum damage during March (3.90%). Mean number of larvae per meter branch length in intercropped plantations (12.36) were significantly lower than in the fallow plantation (16.5). The number of larvae also varied significantly during different months with minimum population during March (0.3) (Fig. 4 b). Similarly, mean number of pupae in fallow plantation (1.75) were significantly higher than intercropped plantation (0.86). Maximum average numbers of pupae per meter branch length in fallow (4.12) and intercropped (2.15) plantation were recorded in October, which was significantly higher than all the other months (Fig. 4 c).

Quinalphos 25 EC, endosulfan 35 EC, profenophos 50 EC, cypermethrin 10 EC, carbaryl 50 WP at the concentrations of 0.025%, 0.05% & 0.1% in the laboratory bio analysis were effective and resulted in 100% mortality of the third instar larvae after 48 h.

During 2003, mean number of larvae per meter branch length varied from 0.13 to 4.26 in treatments compared to 7.53 larvae in control after seven days. The PROC ranged from 20.98 (cypermethrin 10 EC @ 0.025%) to 98.25 (profenophos 50 EC @ 0.1%) during 2003 (Fig. 5 a). Similar trend was observed after 15 days & 21 days. The insecticides quinalphos 25 EC, profenophos 50 EC and carbaryl 50 WP @ 0.05% & 0.1% were significantly (CD 7 DAS = 0.20, 15 DAS = 0.13 and 21 DAS = 0.18 at 5% level of significance) more effective against the defoliator larvae as compared to cypermethrin 10 EC and endosulfan 35 EC @ 0.05% & 0.1%. All treatments were significantly better than control. During 2004 (Fig. 5 b) similar trends were recorded and hence during 2005, only the concentrations of 0.05% & 0.01% were tested owing to consistently poor field performance of 0.025% of all the insecticides during 2003 & 2004. The above mentioned three insecticides proved significantly better performance than endosulphan 35 EC and cypermethrin 10 EC @ 0.05% & 0.01% (CD 7 DAS = 0.71, 15 DAS = 0.19 and 21 DAS = 0.003 at 5% level of significance) (Fig. 5 c).

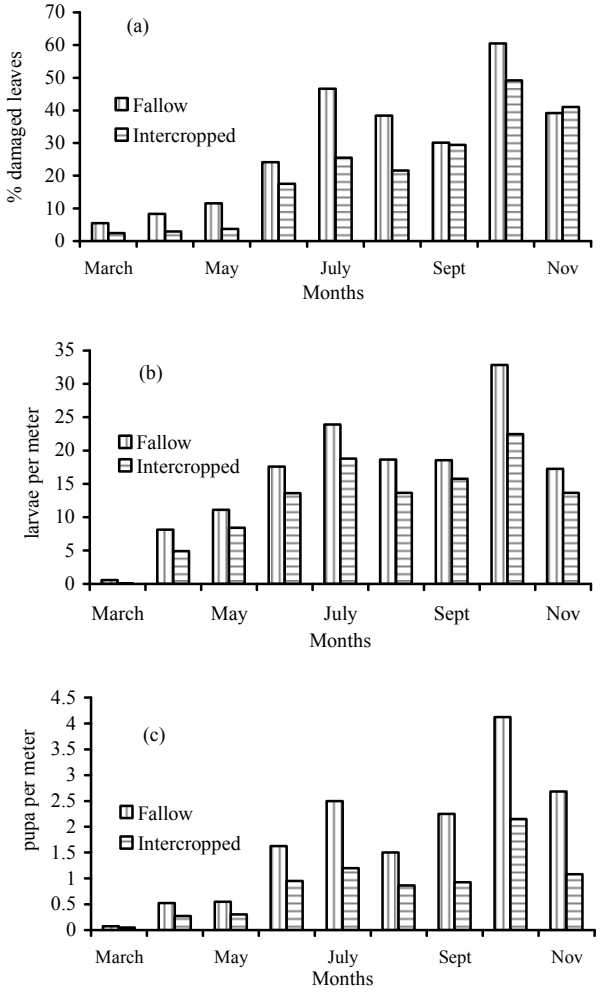

Fig. 4 Percent leaves damaged by *C. fulgurita* (a), larvae of *C. fulgurita* per meter branch (b), and pupae of *C. fulgurita* per meter branch (c) in fallow and intercropped plantations during 2003.

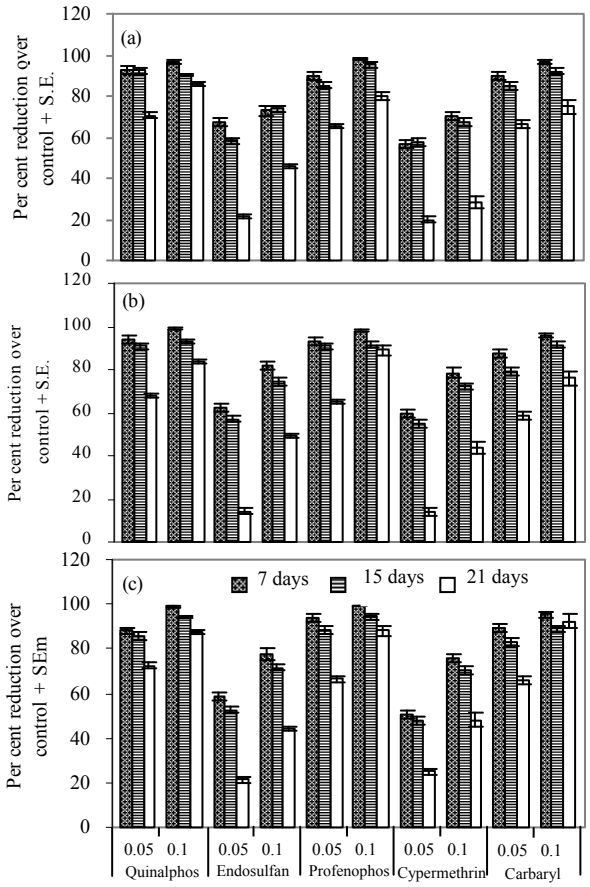

Fig. 5 Percent reduction over control of *Clostera* spp. during 2003 (a), 2004 (b), 2005 (c), with different insecticides at concentrations of 0.05% and 0.1%, respectively.

Pooled analysis (over the years) of data confirmed that Quinalphos 25 EC @ 0.1% (PROC-85.69 at 21 DAS) followed by profenophos 50 EC @ 0.1% (PROC-85.62 at 21 DAS) and Carbaryl 50 WP @ 0.1% (PROC- 80.88 at 21 DAS) were the most effective insecticides against the defoliator larvae exhibiting consistently high PROC up to 21 days.

Discussion

Zonal incidence on extrapolation indicated that *C. restitura* can tolerate relatively much wider range of temperature and humidity owing to its high abundance in central zone (moderate temperature and humidity) and southwestern zone (high temperature and low humidity areas). Higher incidence in southwestern zone of Punjab might be due to the unsuitability of site, poor quality of irrigation water and dry weather conditions for poplar cultivation. However, *C. fulgurita* prefers mild temperature and high humidity areas. Complete defoliation by *C. restitura* was recorded in southwestern districts. However, no such complete defoliation was observed in *kandi* (submountaneous belt) and central zone. This further, substantiates the hypothesis of unsuitability of site in these dry districts leading to susceptibility of Poplar to PLD.

Seasonal variations in population exist in all the agro climatic zones. Population peaks during July and October can be of great value for devising control measures. Timings of sprays just before peak activity periods provided effective control of PLD. The population buildup started from March onwards with the trees acquiring new flush of foliage but remained at low ebb i.e. almost nil till June. Subsequently, the population exploded suddenly into epidemic form, reaching peak in September-October and completely stripped the poplar foliage (Singh et al. 1983). Once the trees are defoliated the larvae descend down the trunk or hang down with silken threads in search of the other trees with foliage. However, no feeding on under growing weeds was observed. Pupation did occur on these weed leaves (Sohi et al. 1987; Thakur 2000). The population load during October is high (higher peaks of leaf damage, larvae & pupae per meter branch length). In epidemic years, the trees are completely stripped of the foliage resulting in re-sprouting of the trees during October. This result in greater stress on trees as they have to compensate for leaf loss just before senescence is starting.

Burying of pupae/ leaf folds with pupae adversely affects the adult emergence. This is further corroborated by low incidence of the PLD in intercropped plantations (also fallow plantations which were ploughed and kept clean of weeds and other undergrowth). Normal cultural practices followed in raising crops lead to damage/ burying of pupae/leaf folds particularly in winter crops (prior to the hibernation of the pupae as poplar is deciduous in nature) and hence, the population buildup in the subsequent year is less. Poplar grown along with crops gets proper care resulting in healthy and robust stand, which is inherently less prone to defoliator attack.

In case of fallow plantations, deep ploughing especially during December when all the leaves have been shed gives similar results as intercropped plantations. Simple collection and burying of fallen leaf folds/ leaves is also a useful practice. This filed behaviour of the defoliator larvae has helped in devising sprays application during evening hours. This has resulted in better control of the PLD as the amount of spray material reaching the leaves is more in the lower canopy of the trees. Further, timing of the sprays just before peak activity periods helps in efficient and prolonged control of the PLD.

Quinalphos 25 EC, profenophos 50 EC and carbaryl 50 WP @ 0.05% and 0.1% were found effective in the management of PLD. The results are corroborated by Singh et al. (1983) who also recorded carbaryl 50 WP @ 1 kg a.i./ha (aerial spray) to give 99.1% kill of *Clostera cupreata* in tarai region of Uttar Pradesh. Sohi et al. (1987) have reported in earlier studies that fenvelrate, monocrotophos and quinalphos @ 0.05% proved more effective and provided 86–94.3% kill after one day of treatment. All treatments except monocrotophos remained effective up to seven days, whereas monocrotophos remained effective up to 15 days. Fenitrothion (0.04%), endosulfan (0.04%), monocrotophos (0.05%) and Quinalphos (0.05%) were effective in management of poplar defoliators in Tarai belt of Uttar Pradesh (Thakur 2000). The ovicidal effect of synthetic pyrethroids against *C. fulgurita* eggs at Dehra Dun has been documented by Veer et al. (1992). The study revealed that percentage of unhatched eggs increased with the corresponding increase in concentration of deltamethrin,

cypermethrin and permethrin from 0.00005% to 0.005%. Further the development of eggs was slowed down as the treated eggs hatched after three days whereas the untreated ones hatched after two days. Deltamethrin showed maximum ovicidal activity among the pyrethroids. In the present study, cypermethrin 10 EC and endosulfan 35 EC were the least effective against the larvae. However, in present study we did not record the effect of this insecticide on the eggs. PLD has 8–10 overlapping generations during a year and hence all life stages are available in the field at any particular time (March-November) (Sangha 2004). The eggs are primarily laid in masses on the undersurface of leaves and the probability of their exposure to insecticides is reduced. The pupation takes place in leaf folds on the trees and also on the ground during winters. Control of larvae of PLD is a better preposition for effective management of PLD.

All the attempts at managing this pest so far have been isolated, single, site specific and on a limited scale. The present study is a concerted attempt over the years for establishment of effective management strategy for the whole Punjab state. The usage of quinalphos 25 EC, profenophos 50 EC and carbaryl 50 WP @ 0.05% & 0.1% particularly prior to peak activity periods (July & October) will lead to comprehensive control of the poplar leaf defoliators

Acknowledgement

Author extends his sincere thanks to Punjab State Forest Department for providing financial assistance under JBIC assisted projects to carry out this research work.

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